Innovative løsninger til modstandssvejsning af nye materialekombinationer

Nielsen, Chris Valentin; Moghadam, Marcel

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Chris Valentin Nielsen og Marcel Moghadam, DTU-MEK

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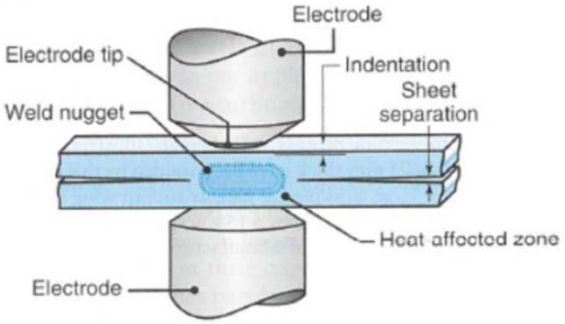
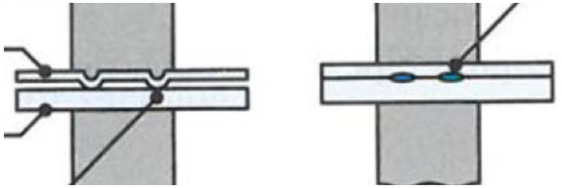
Dansk Svejseteknisk Landsforening
Svejse- og NDT-seminar 21.-22. maj 2019, Koldingfjord

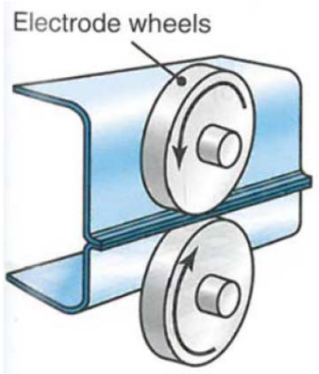
Modstandssvejsning

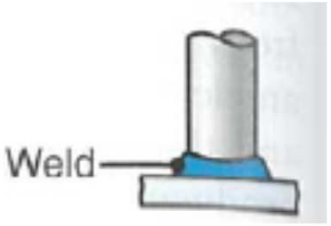
Forskellige typer af modstandssvejsning

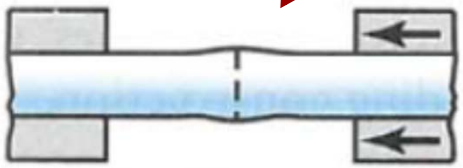
- Punktsvejsning (spot welding)
- Pressvejsning (projection welding)
- Sømsvejsning (seam welding)
- Stumpsvejsning (butt welding)
- Bolte-/tapsvejsning (stud welding)



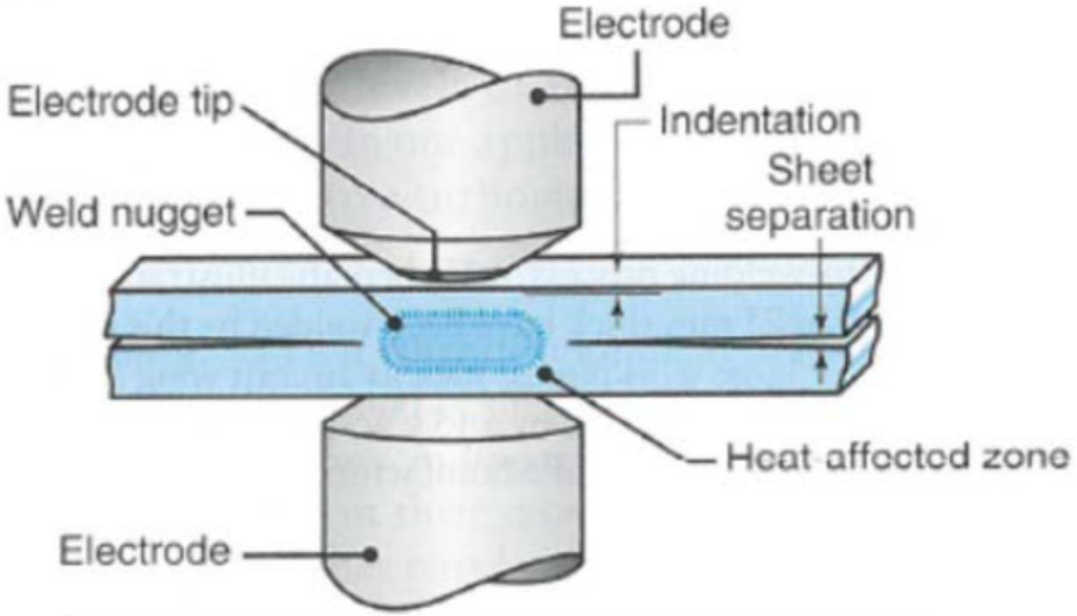


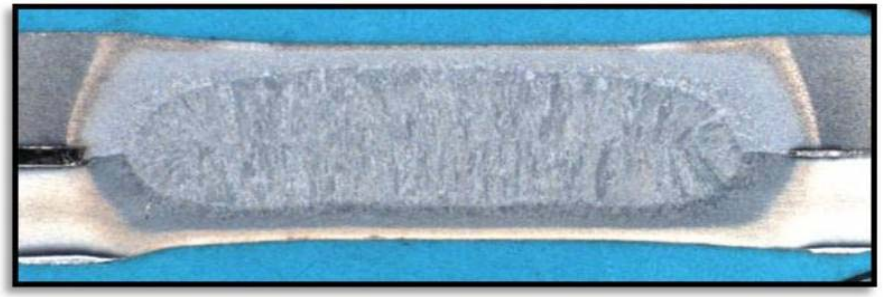






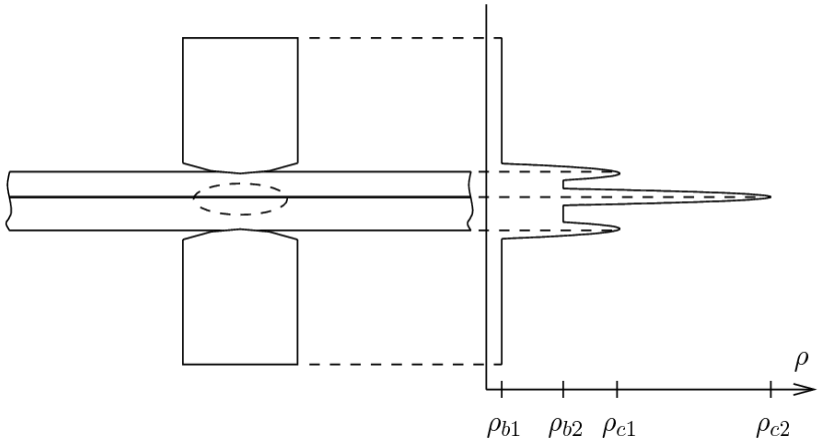
Punktsvejsning



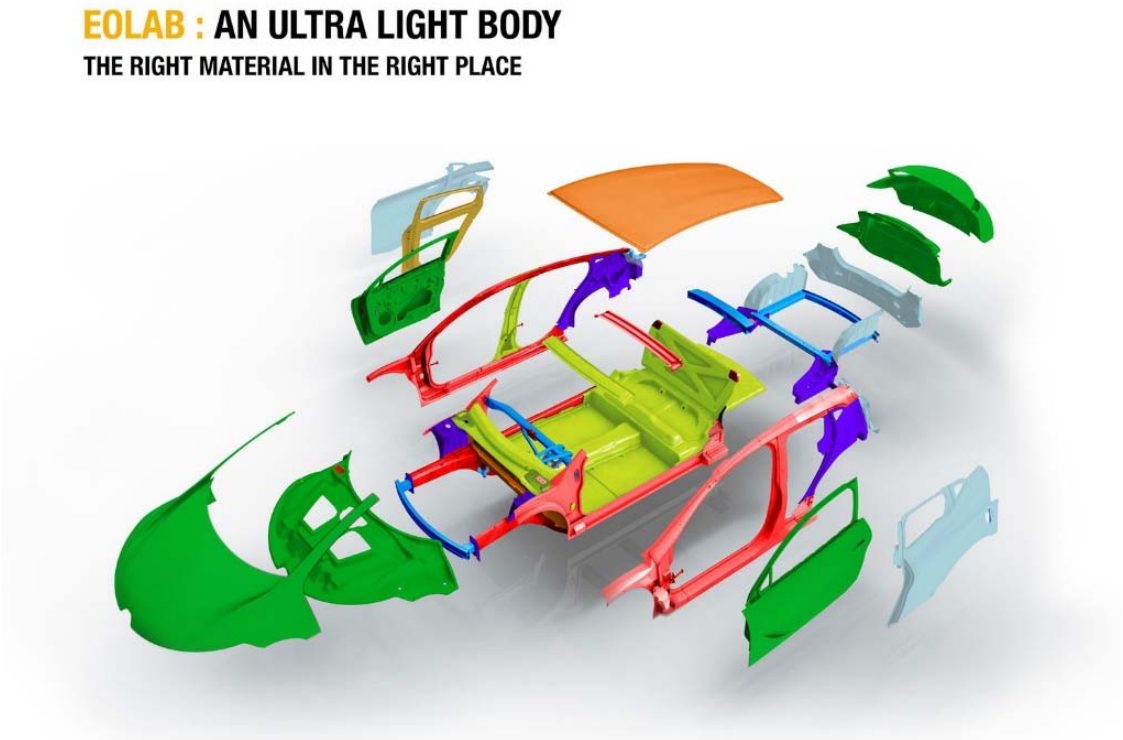


Varmegenerering:

$$q = \int_{t_1}^{t_2} \rho(t)\, J(t)^2\, dt$$



Nye materialekombinationer



https://www.carbodydesign.com/gallery/2014/09/renault-eolab-ultra-efficient-concept/31/

STEELS
- Advanced very high strength
- Ultra high strength
- Hot stamping ultra high strength
- Advanced hot stamping ultra high strength

MAGNESIUM
- Stamped
- Casting

ALUMINIUM
- Stamped
- Extruded
- Casting

THERMOPLASTICS
- Continuous fiber reinforced
- Injected glass fiber reinforced

\+ Sandwichstrukturer

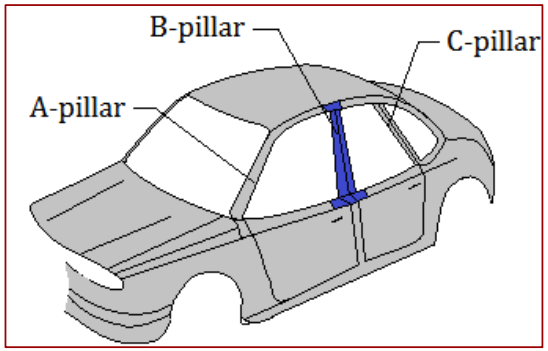
Materialekombinationer i denne præsentation

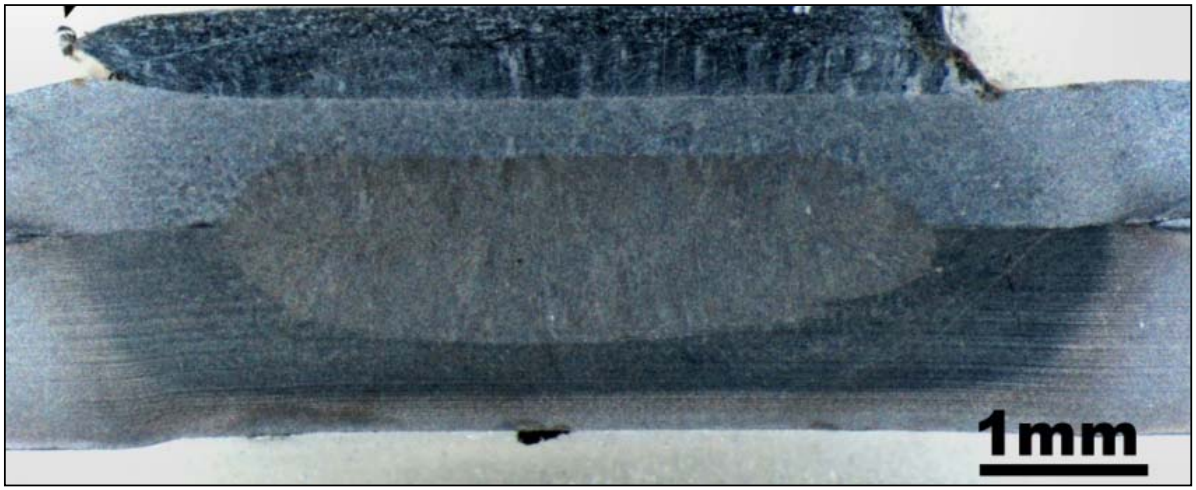
- Stål-stål
- Aluminium-aluminium
- Magnesium-magnesium
- Stål-aluminium
- Stål-messing
- Metal-polymer

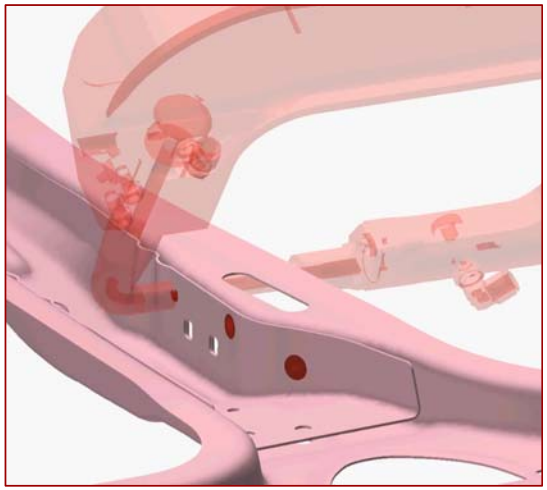
Stål-stål: Typisk tre-lags

Eksempel

- 0.6mm DC06
- 0.8mm HSLA 340
- 1.2mm galvaniseret TRIP700

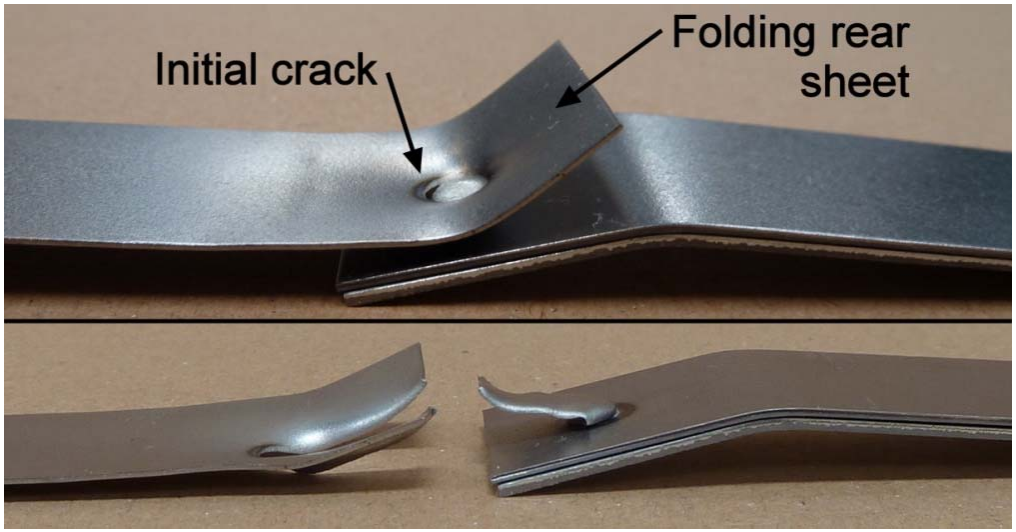


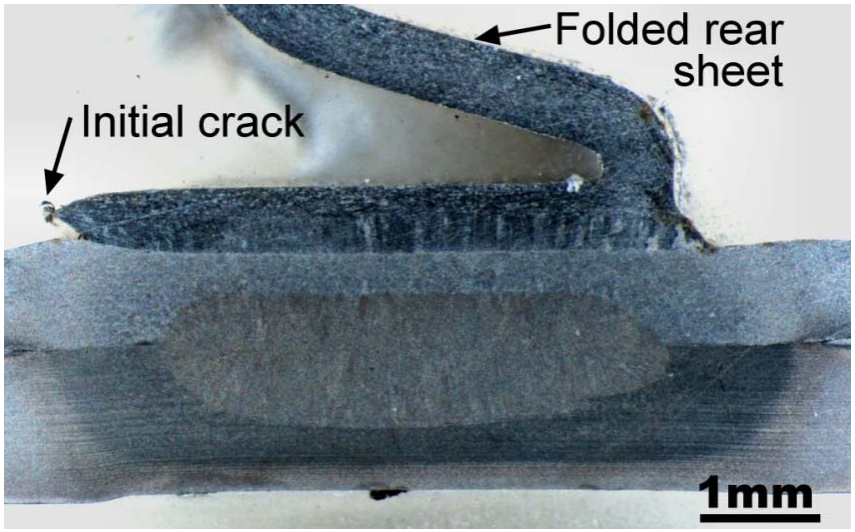




Stål-stål: Typisk tre-lags

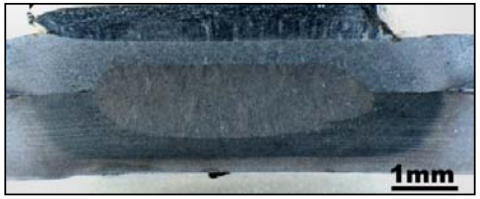
Plug failure uden svejselinse i den øverste interface





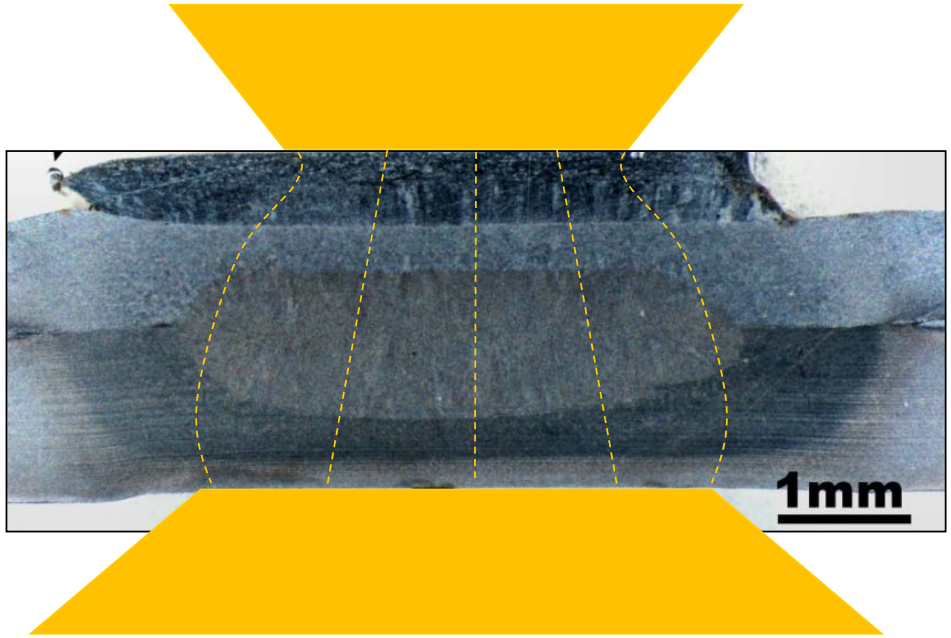
Nielsen, C.V., Friis, K.S., Zhang, W. and Bay, N. (2011): Three-Sheet Spot Welding of Advanced High-Strength Steels. Welding Journal 90(25), 32-40.

Stål-stål: Typisk tre-lags



Hvordan får vi svejselinsen ind i den tynde plade?

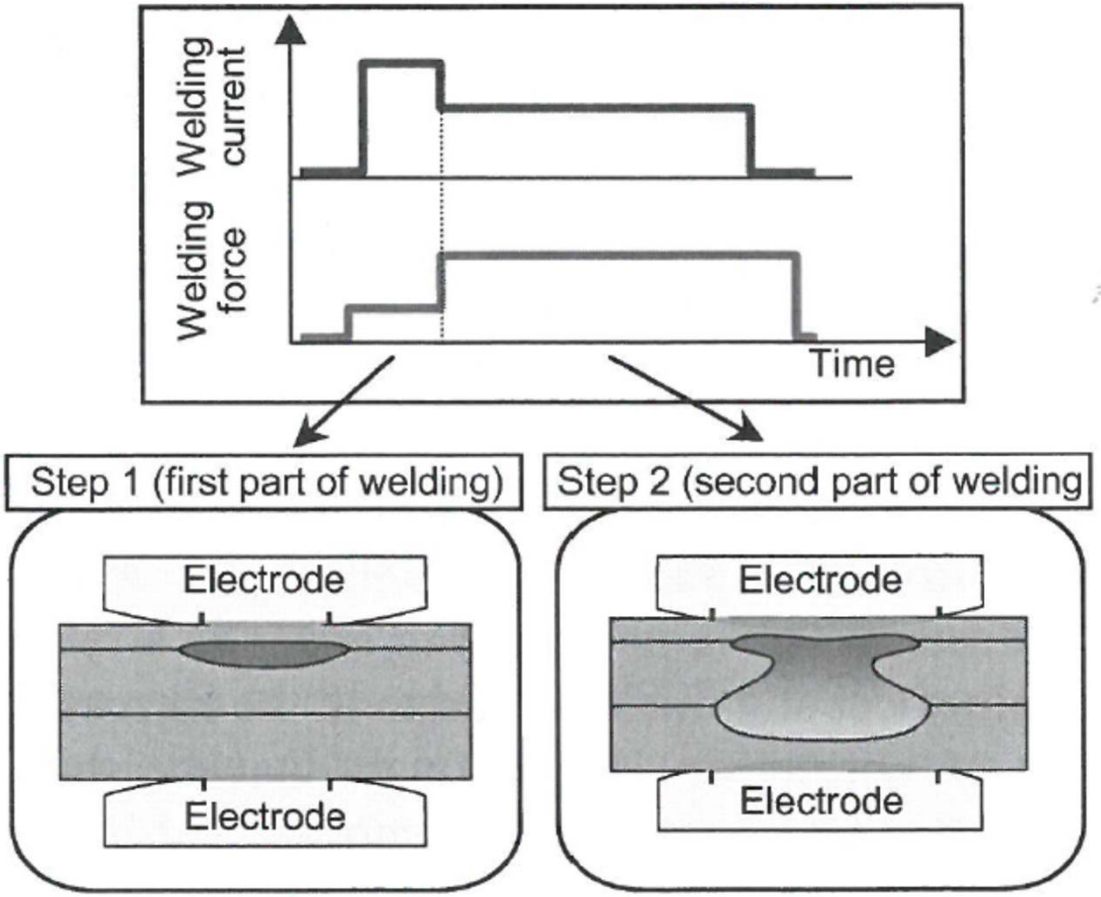
- Forskellige elektrodestørrelser



Stål-stål: Typisk tre-lag

Hvordan får vi svejselinsen ind i den tynde plade?

- Forskellige elektrodestørrelser
- ”Intelligent Spot Welding”
  (JFE Steel)

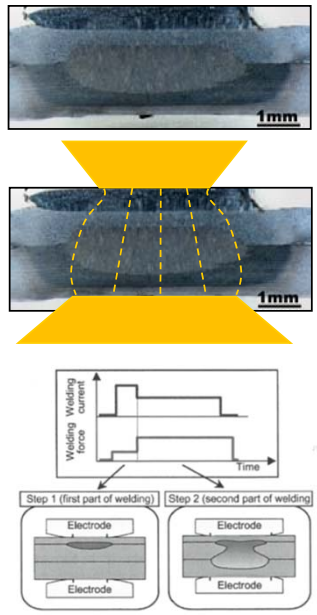


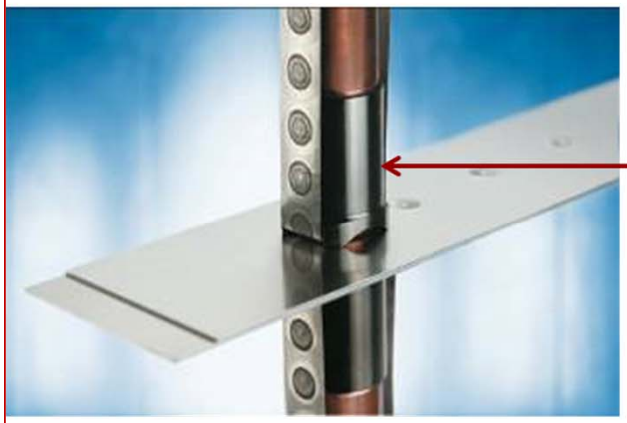
Ikeda, R., Okita, Y. and Ono, M. (2008): Development of new resistance spot welding process for three sheet joints using electrode force control. Proceedings of the 5th International Seminar on Advances in Resistance Welding, Toronto, Canada, 105-113.

Stål-stål: Typisk tre-lags

Hvordan får vi svejselinsen ind i den tynde plade?

- Forskellige elektrodestørrelser
- ”Intelligent Spot Welding” (JFE Steel)
- Delta Spot (Fronius)

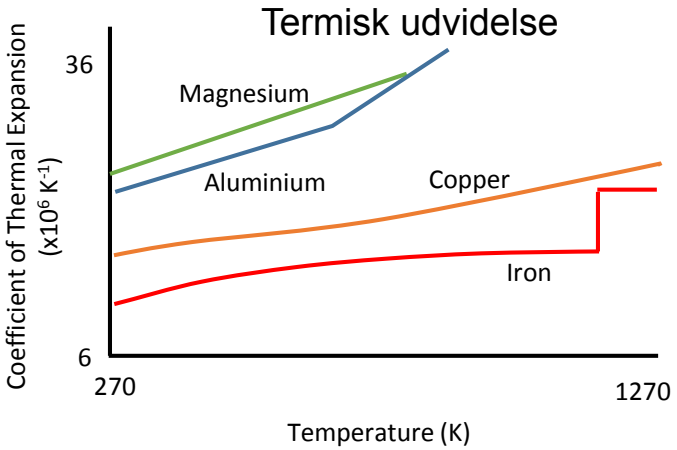


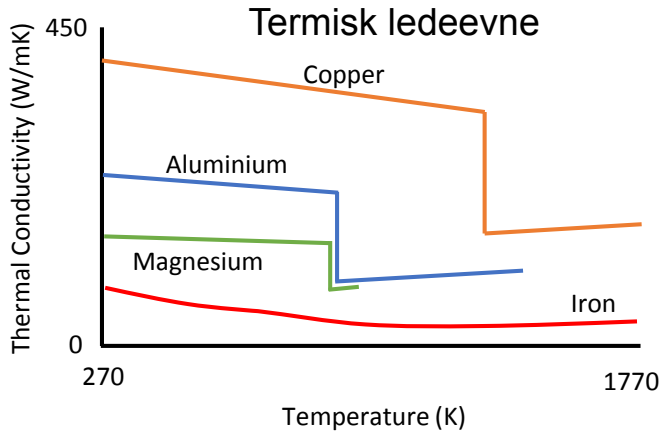


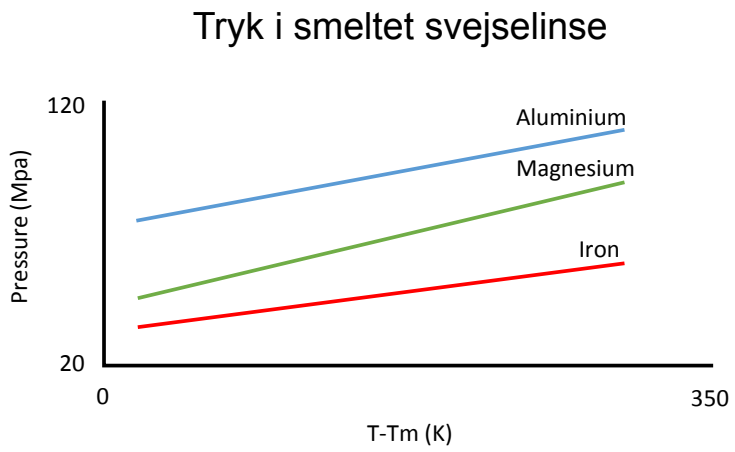
Delta Spot-tapen indeholder flere lag og fås med forskellig resistivitet

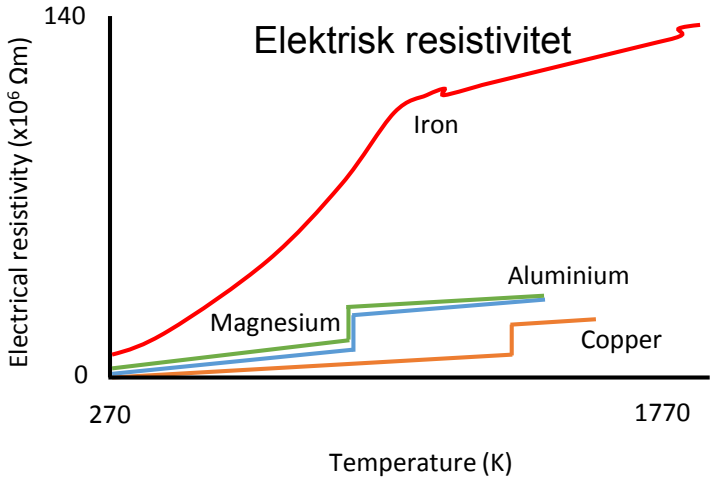
Bećirović, A. (2014): Delta spot tapes in SORPAS. Proceedings of the 8th International Seminar on Advances in Resistance Welding, Baveno, Italy, 120-126.

Generelle materialeegenskaber









Redrawn from: Luo, H, Hao, C., Zhang, J., Gan, Z., Chen, H. and Zhang, H. (2011): Characteristics of resistance welding magnesium Alloys AZ31 and AZ91. Welding Journal 90(12), 249s-257s.

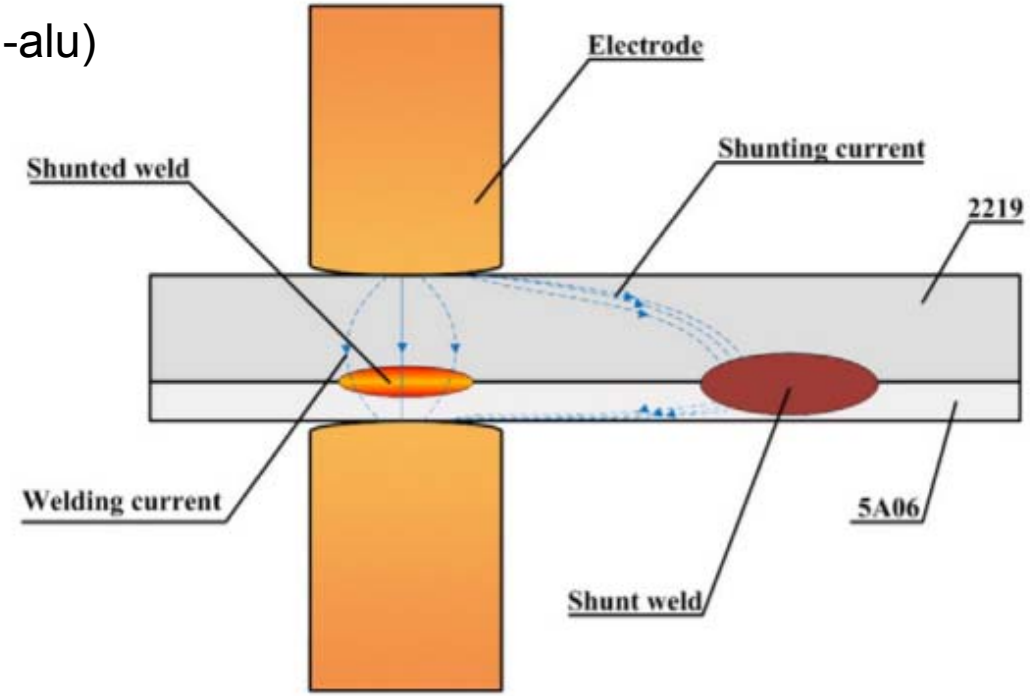
Aluminium-aluminium & magnesium-magnesium

Udfordringer:

- Lav elektrisk resistivitet og god termisk ledeevne
- Shunting
  - Mere på kommende slides
- Elektrodeslid
  - Mere på kommende slides
- Porøsiteter
  - Hurtig køling og evt. hydrogen som ikke opløses i det størknede materiale
- Sprøjt
  - Dårlig kontakt mellem elektrode og plade, især efter elektrodeslid
- Liquation cracking
  - Kombination af termiske spændinger og svage eutektoide legeringer (Mg)

Aluminium-aluminium & magnesium-magnesium

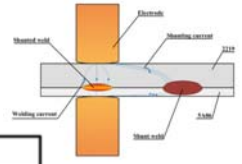
Shunting (Alu-alu)

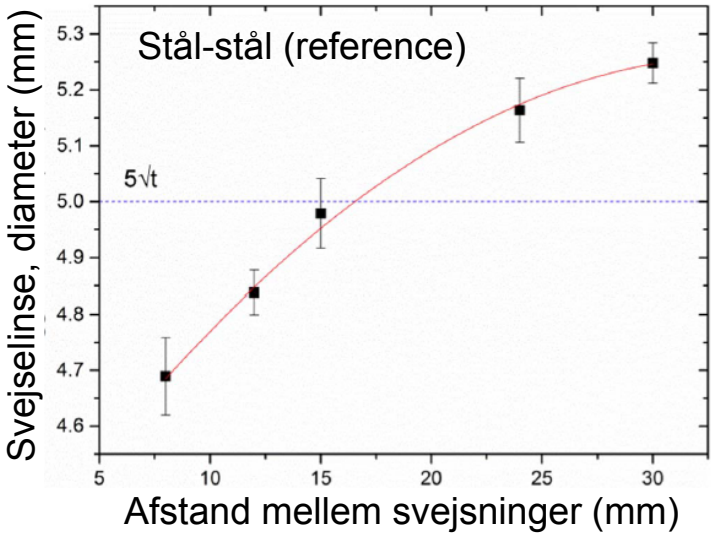


Bi, J., Song, J., Wei, Q., Zhang, Y., Li, Y. and Luo, Z. (2016): Characteristics of shunting in resistance spot welding for dissimilar unequal-thickness aluminum alloys under large thickness ratio. Materials and Design 101, 226-235.

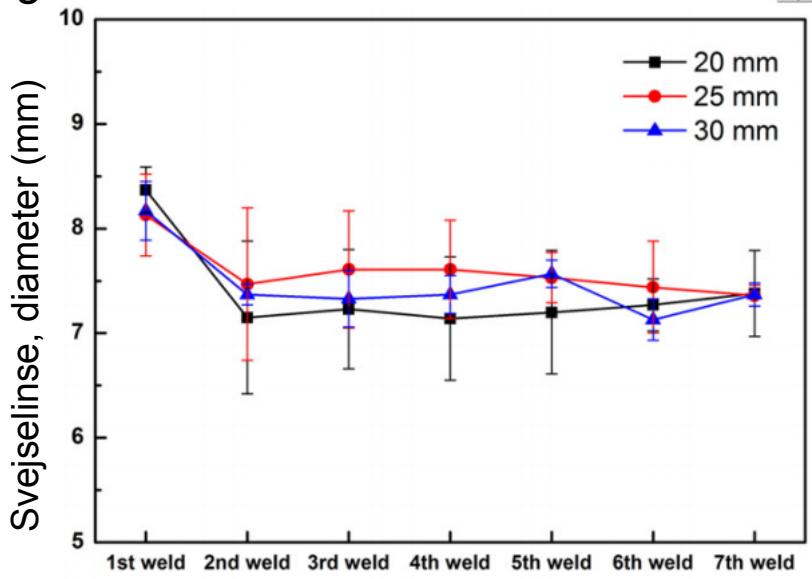
Aluminium-aluminium & magnesium-magnesium

Shunting – Sammenligning mellem stål og aluminium





Li, Y.B., Wang, B., Shen, Q., Lou, M. and Zhang, H. (2013): Shunting Effect in Resistance Spot Welding Steels—Part 2: Theoretical Analysis. Welding Journal 92(8), 231s-238s.



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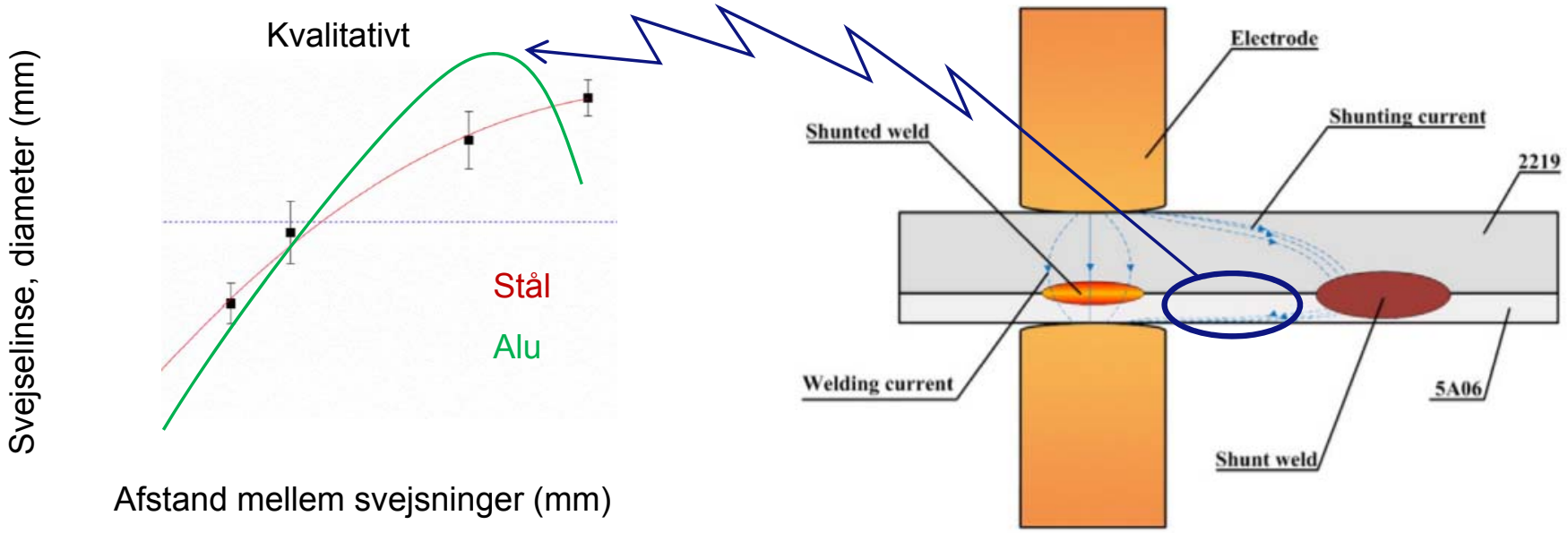
Aluminium-aluminium & magnesium-magnesium

Shunting – Sammenligning mellem stål og aluminium

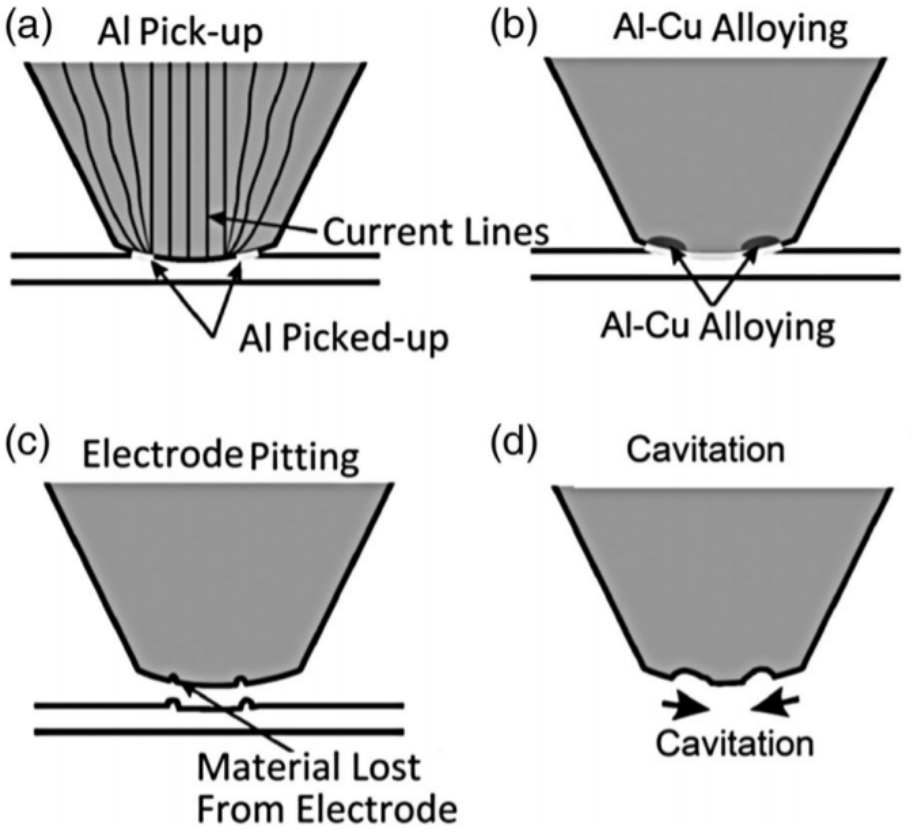


Toppen på alu-kurven skyldes opvarmning og deraf forhøjet modstand i den tynde aluminiumplade.

Heraf mindskes shunt-effekten.

Aluminium-aluminium & magnesium-magnesium

- Elektrodeslid i aluminium

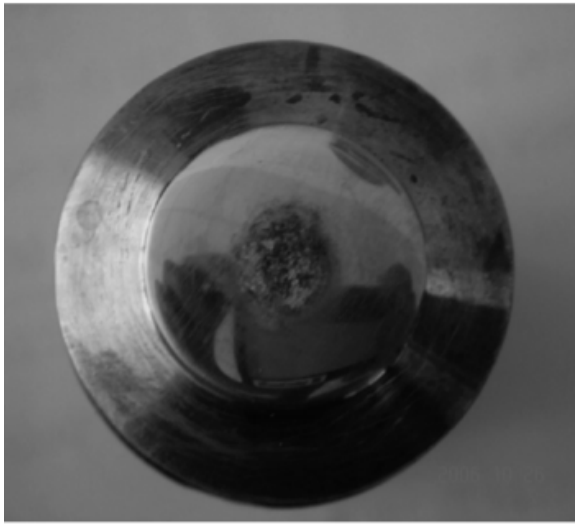


Zhang, W.J., Cross, I., Feldman, P., Rama, S., Norman, S. and Del Duca, M. (2017): Electrode life of aluminium resistance spot welding in automotive applications: a survey. Science and Technology of Welding and Joining 22(1), 22-40. Figures compiled from: Lum, I., Biro, E., Zhou, Y., Fukumoto, S. and Boomer, D.R. (2004): Electrode pitting in resistance spot welding of aluminum alloy 5182. Metallurgical and Materials Transactions A 35(1), 217-226.

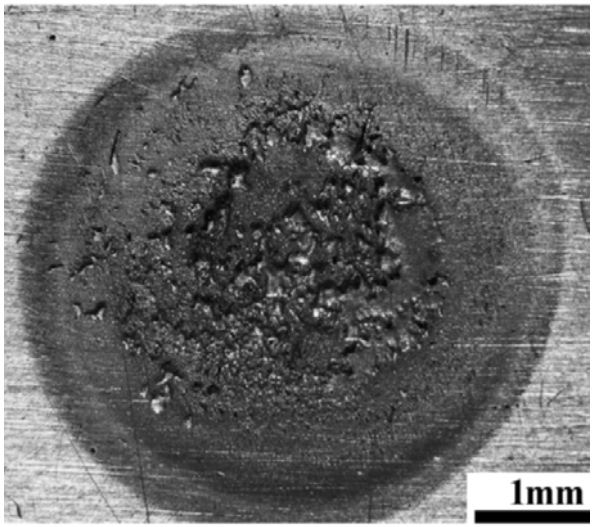
Aluminium-aluminium & magnesium-magnesium

- Elektrodeslid i magnesium
  - Billeder efter 25 punktsvejsninger

Elektrode



Plade efter svejsning

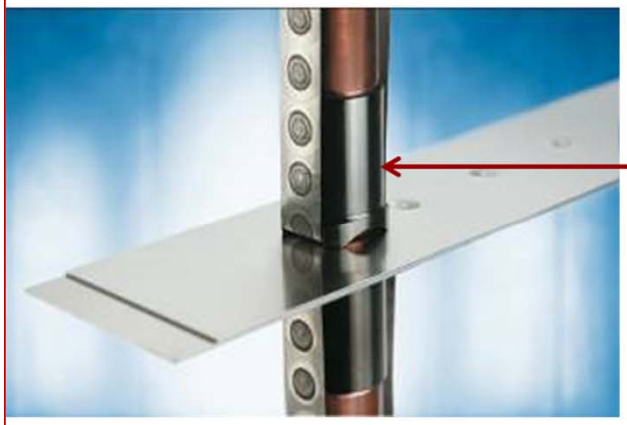


Lang, B., Sun, D.Q., Li, G.Z. and Zhu, B.Q. (2009): Electrode Degradation in Resistance Spot Welding of Magnesium Alloy. ISIJ International 49(11), 1744-1748.

Aluminium-aluminium & magnesium-magnesium

Løsninger

- Delta Spot (Fronius) afhjælper elektrodeslid og giver samme forhold i hver svejsning når tapen flyttes mellem hver svejsning



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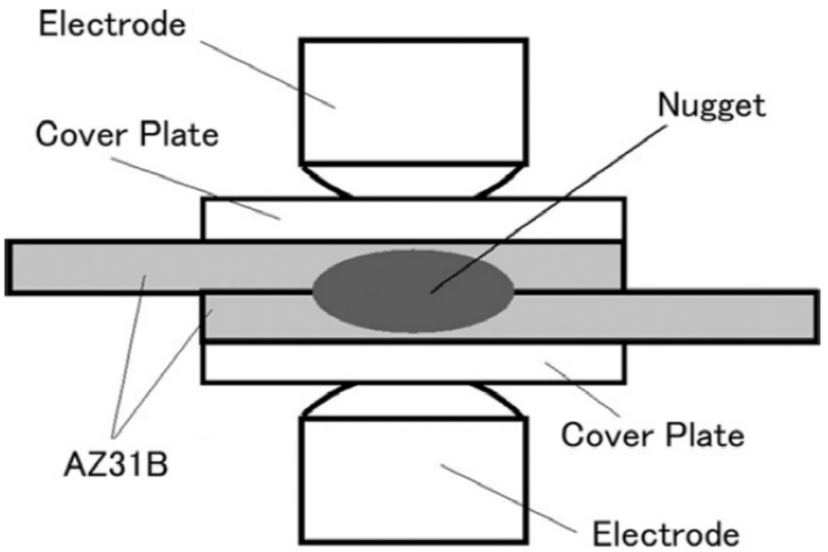
Aluminium-aluminium & magnesium-magnesium

Løsninger

- Brug af stål-cover plates til svejsning af Al-Al og Mg-Mg
  - Mere varme kan generes
  - Mere jævn varmefordeling
  - Mindre elektrodeslid
  - Cover plates kan flyttes til næste svejsning
    - Fastgøres ikke til Al/Mg pga. forskellig termisk udvidelse

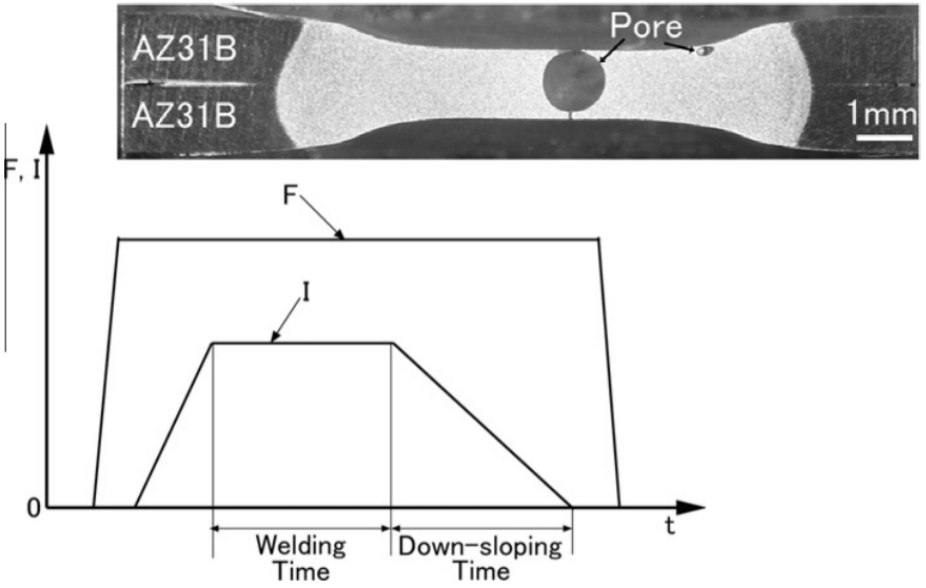


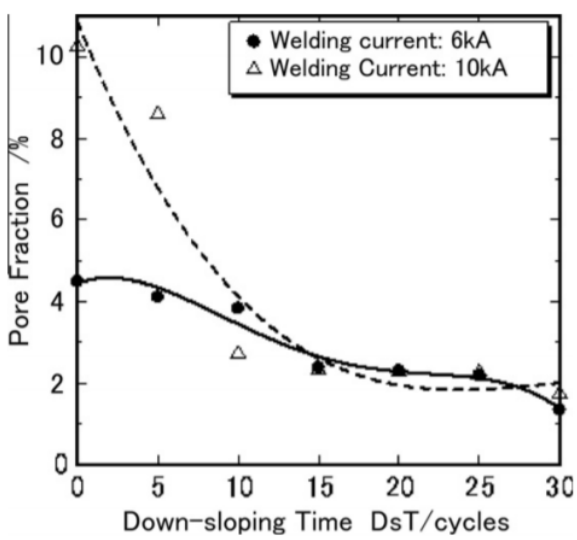
Shi, H., Qiu, R., Zhu, J., Zhang, K., Yu, H. and Ding, G. (2010): Effects of welding parameters on the characteristics of magnesium alloy joint welded by resistance spot welding with cover plates. Materials and Design 31, 4853-4857.

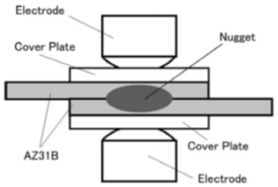
Aluminium-aluminium & magnesium-magnesium

Løsninger

- Down-slope og øget elektrodekraft mindsker dannelsen af porøsiteter (Mg-Mg)







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Aluminium-aluminium & magnesium-magnesium

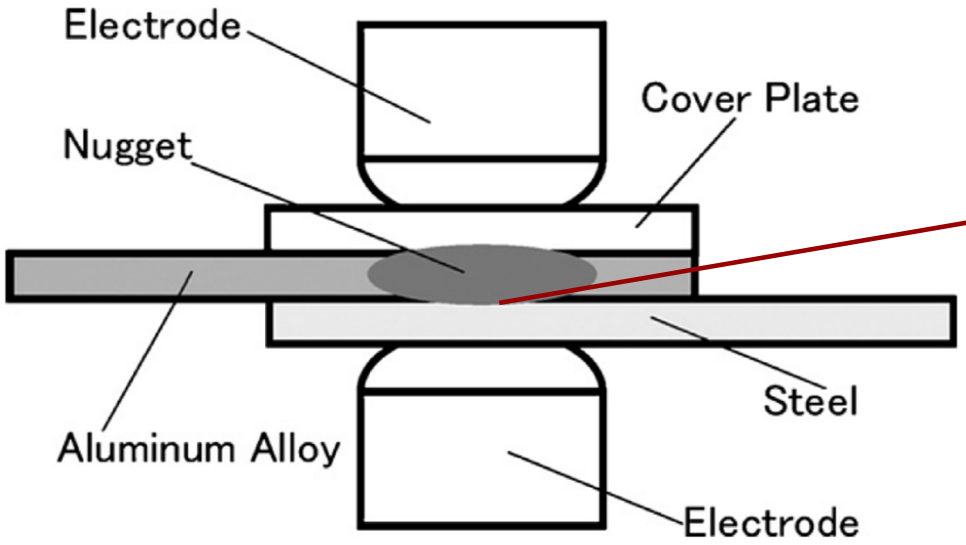
Huys Industries: TiCaps™

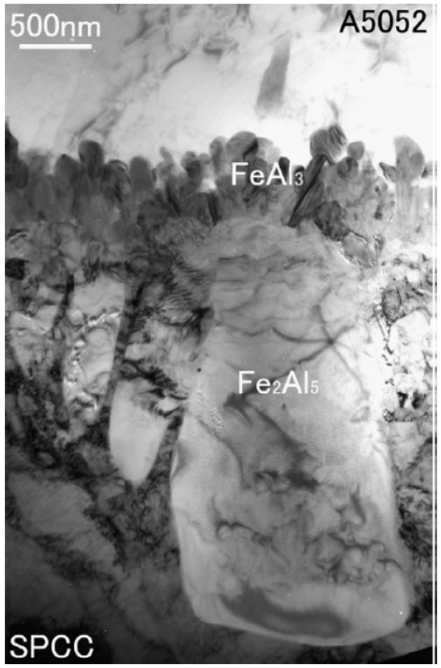
- Mindre elektrodeslid
- Større processvindue

Huys Industries: Huys Technical Library #32
www.huysindustries.com

Stål-aluminium

Også her anvendes en cover plate for at forbedre varmebalancen

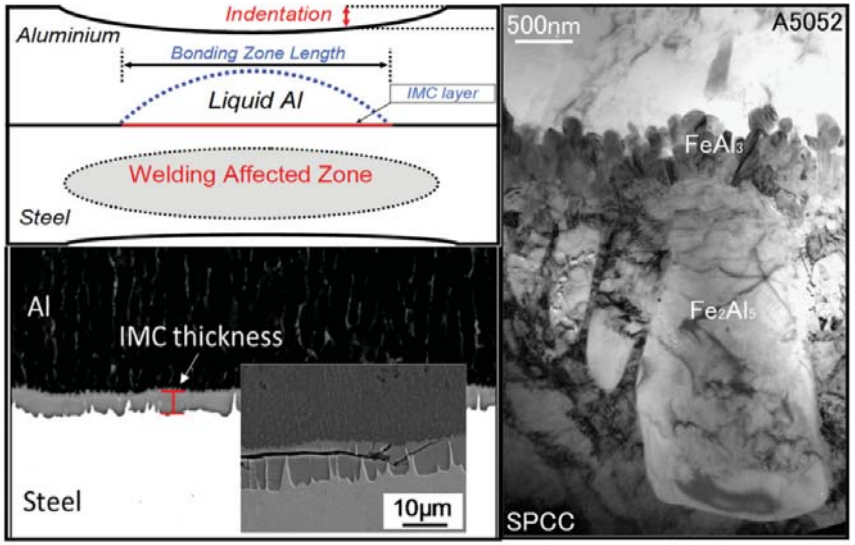




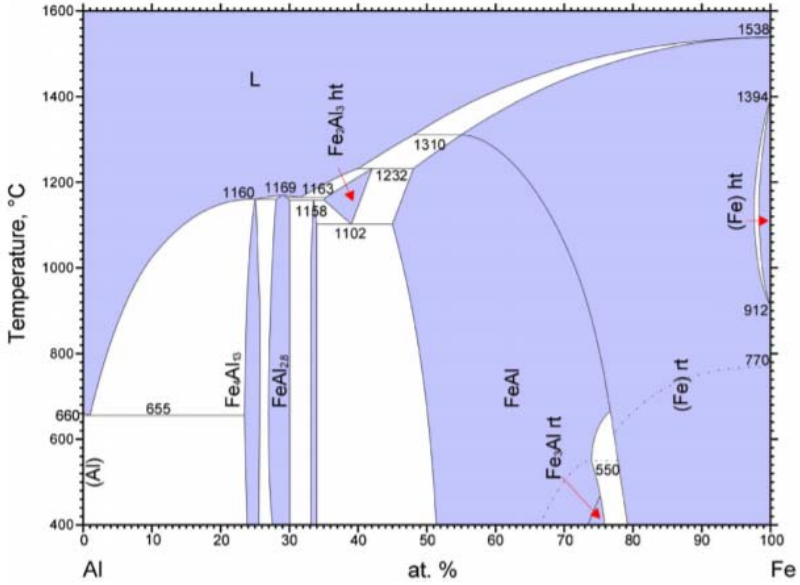
Qiu, R., Iwamoto, C. and Satonaka, S. (2009): Interfacial microstructure and strength of steel/aluminum alloy joints welded by resistance spot welding with cover plate. Journal of Materials Processing Technology 209, 4186-4193.

Stål-aluminium

Sprøde intermetalliske forbindelser



Pouranvari, M. (2017): Critical assessment 27: dissimilar resistance spot welding of aluminium/steel: challenges and opportunities. Materials Science and Technology 33(15), 1705-1712.



Schneider, J. and Radzilowski, R. (2014): Welding of Very Dissimilar Materials (Fe-Al). JOM 66(10), 2123-2129.

Stål-aluminium

Fejltyper

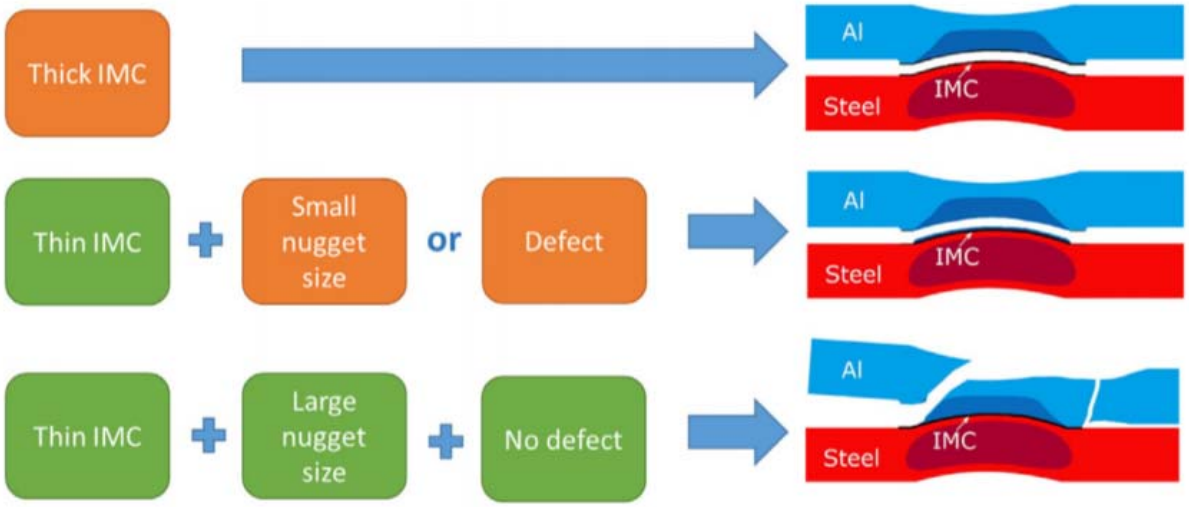
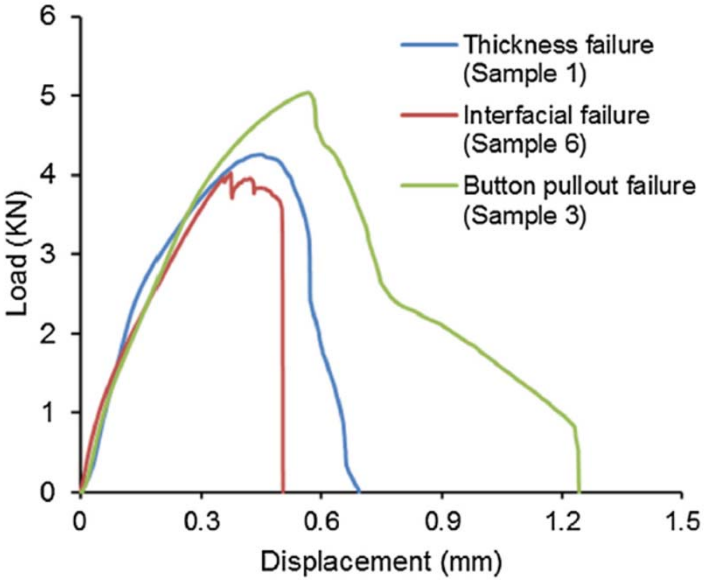


Fig. 19. Factors affecting lap shear failure mode of Al/steel RSWs.



Chen, N., Wang, H.-P., Carlson, B. E., Sigler, D. R. and Wang, M. (2017): Fracture mechanisms of Al/steel resistance spot welds in lap shear test. Journal of Materials Processing Technology 243, 347-354.

Stål-aluminium

Løsninger

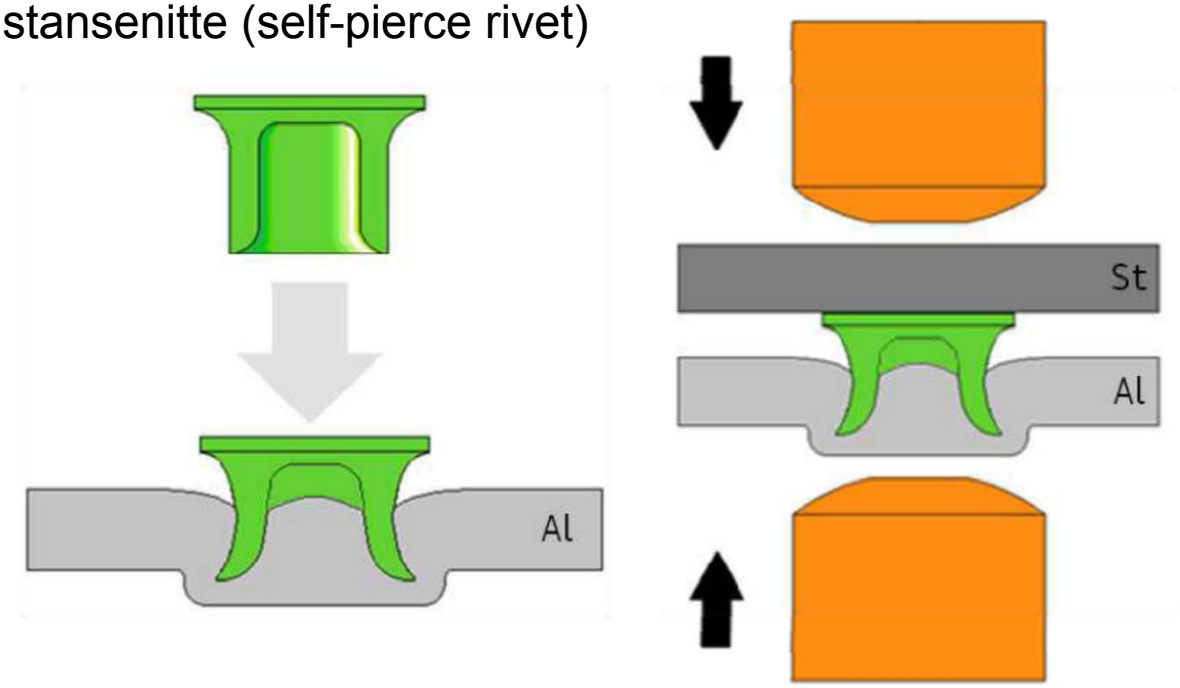
- Kort svejsetid (og derfor høj strømstyrke) mindsker tykkelsen af det sprøde intermetalliske lag.
- Brug af cover plate øger størrelsen af sammenføjningen.
- Zinc-coating på stål
  - smelter tidligt og giver en 'ren' ståloverflade til bindinger.
  - mindsker modstanden og varmegenerering i interfacen, og giver derved et tyndere intermetallisk lag.
- AlSi-coating på stål:
  - Tilstedeværelsen af Si mindsker dannelsen af det intermetalliske lag.

Pouranvari, M. (2017): Critical assessment 27: dissimilar resistance spot welding of aluminium/steel: challenges and opportunities. Materials Science and Technology 33(15), 1705-1712.

Stål-aluminium

Endnu en løsning…

- Brug af stansenitte (self-pierce rivet)

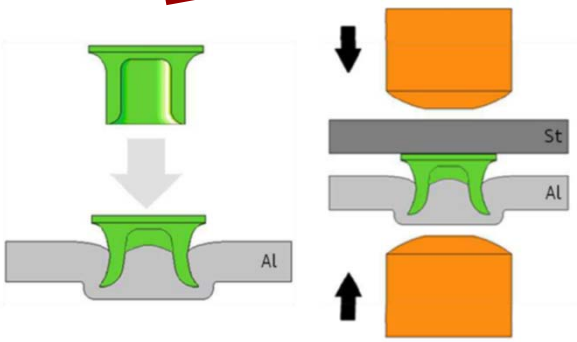


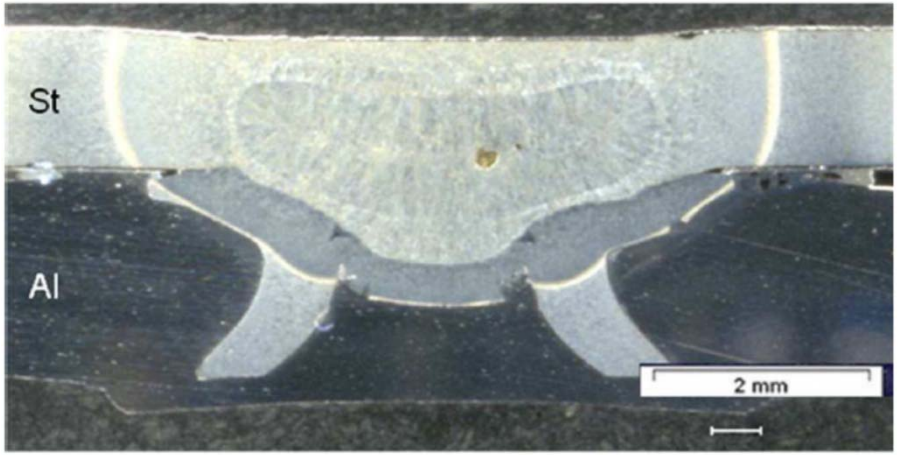
Kotschote, C., Neudel, C., Bergman, J.P. and Rudolf, H. (2013): DVS Congress Grosse Schweisstechnische Tagung. DVS Media, 88-92.

Stål-aluminium

Endnu en løsning…

- Brug af stansenitte (self-pierce rivet)

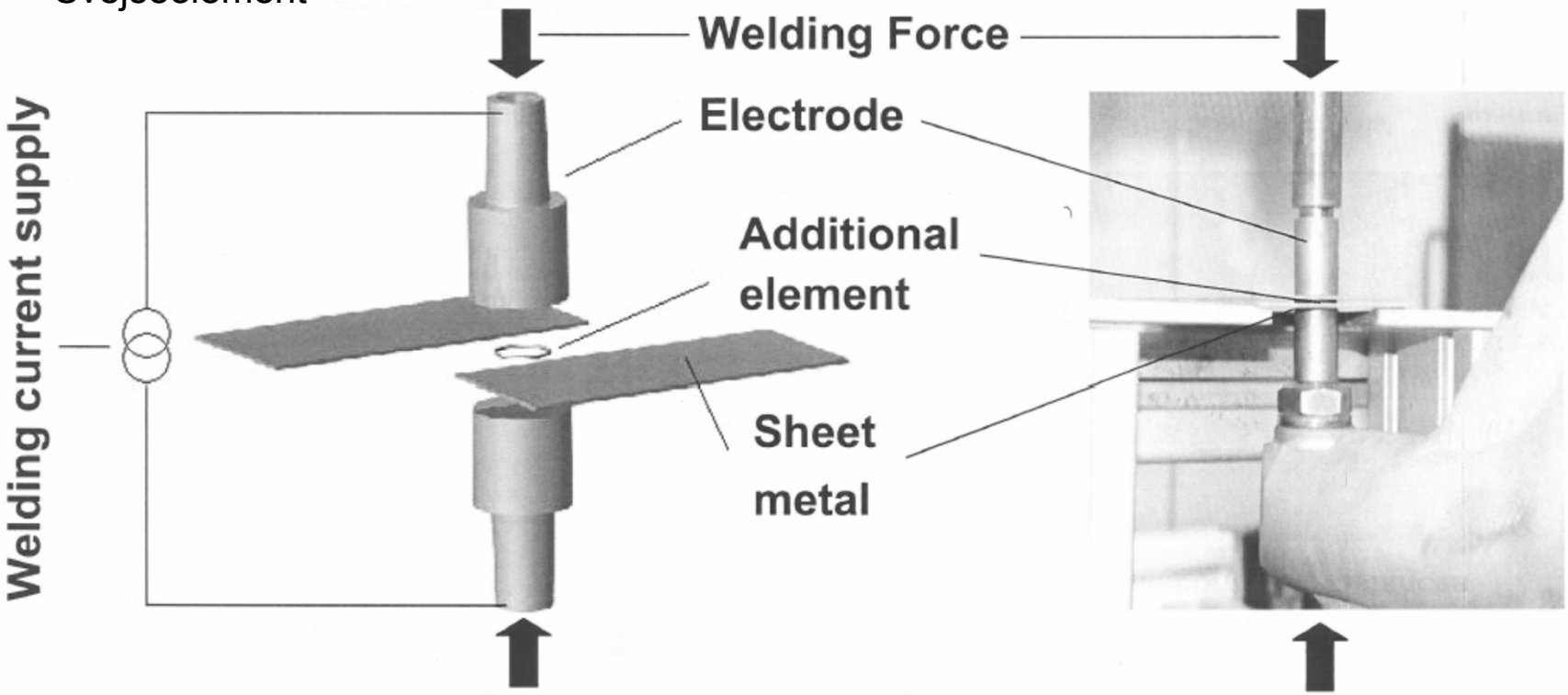




Kotschote, C., Neudel, C., Bergman, J.P. and Rudolf, H. (2013): DVS Congress Grosse Schweisstechnische Tagung. DVS Media, 88-92.

Stål-messing

Svejseelement



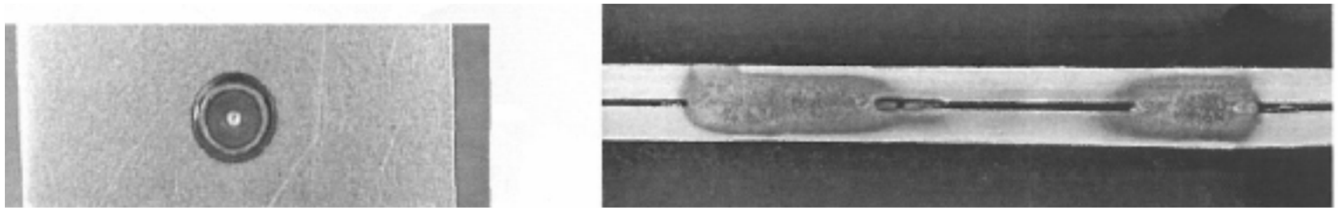
Koppe, K., Jüttner, S., Graul, M. and Rudolf, H. (2002): Simulation of innovative resistance welding processes. Proceedings of the 2nd International Seminar on Advances in Resistance Welding, Aachen, Germany.

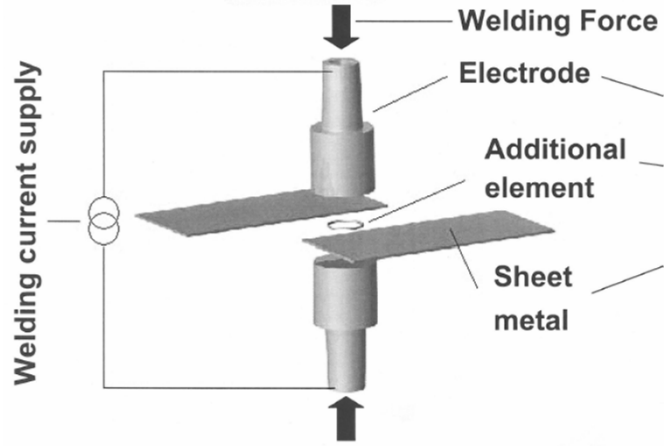
Stål-messing

Svejseelement

- Fra punktsvejsning mod pressvejsning
  - Varmebalance bestemt af geometri
- Men med tilførsel og positionering af ekstra materiale.

Messing - Stål 37



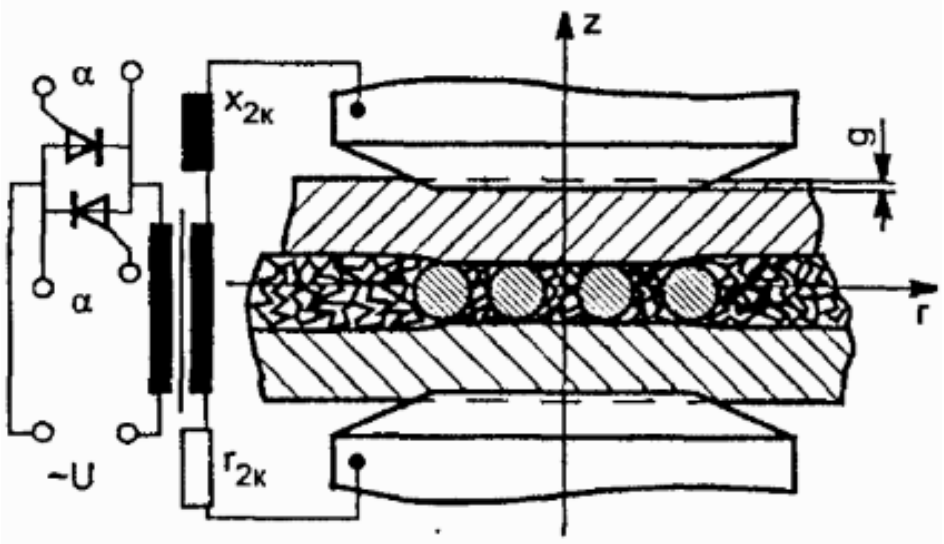


Koppe, K., Jüttner, S., Graul, M. and Rudolf, H. (2002): Simulation of innovative resistance welding processes. Proceedings of the 2nd International Seminar on Advances in Resistance Welding, Aachen, Germany.

Polymerer

Metal-polymer-metal punktsvejsning

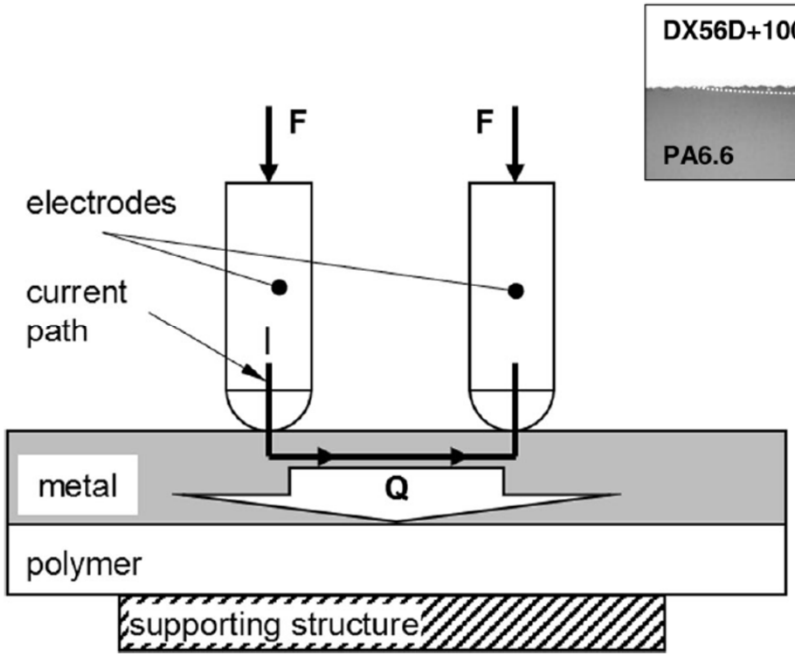
- Zink-granulat i polymeren som elektrisk leder.
- Effektiv punktsvejsning-
- Store elektrodeindtryk.

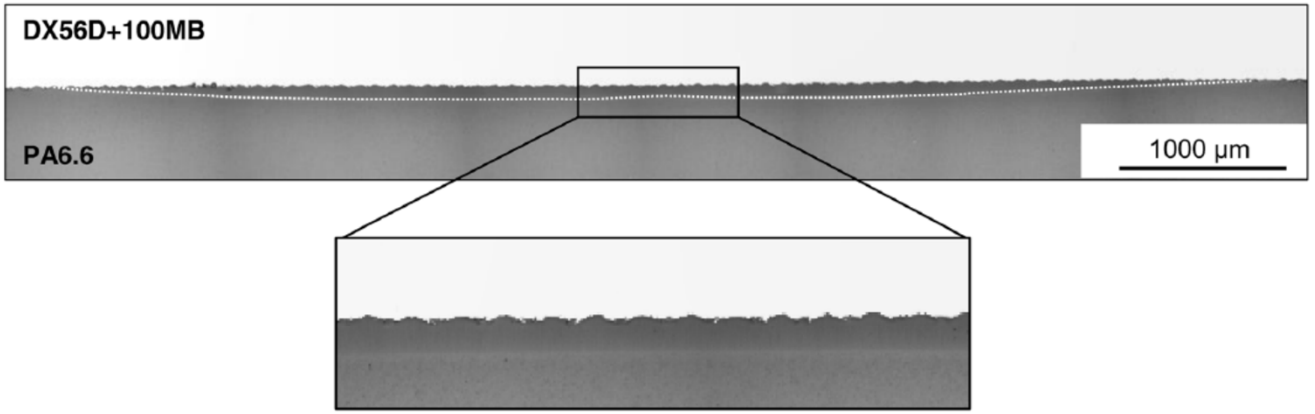


Frolov, V.A., Menshikov, G.A. and Efremov, S.V. (2002): Development of a method of joining metal-polymer materials by resistance welding. Welding International 16(9), 750-752.

Polymerer

Metal-polymer, modstandsopvarmet binding



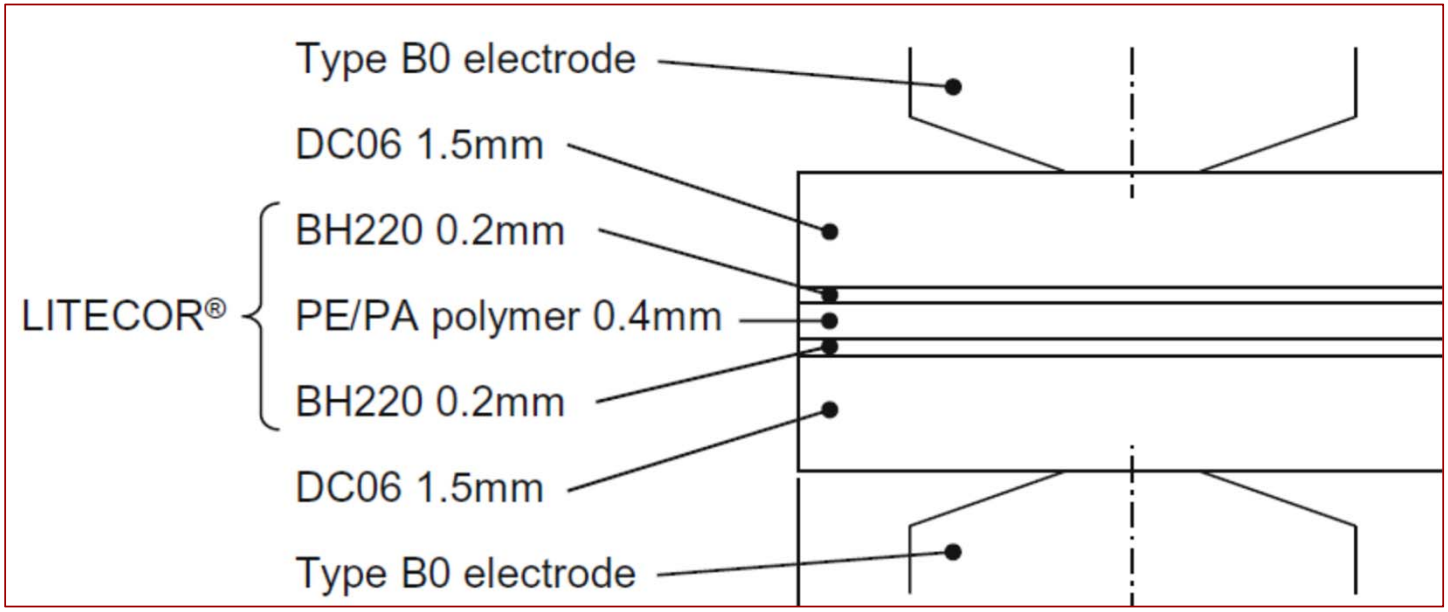


Szallies, K., Bielenin, M., Schricker, K., Bergmann, J.P. and Neudel, C. (2019): Single-sided resistance spot joining of polymer-metal hybrid structures. Welding in the World (doi.org/10.1007/s40194-019-00728-x).

Polymerer

Stål – Sandwich – Stål

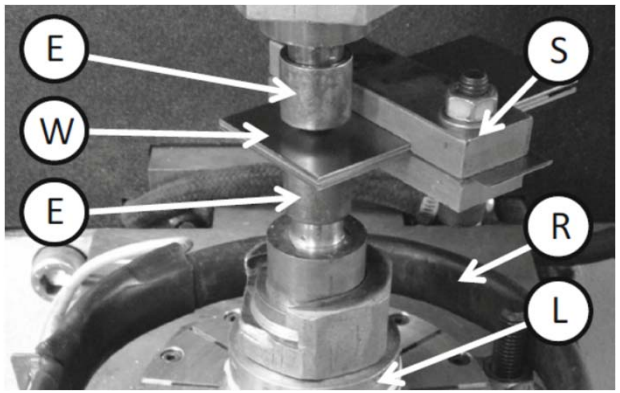
- Sandwich = Stål-polymer-stål uden metalpartikler i polymeren

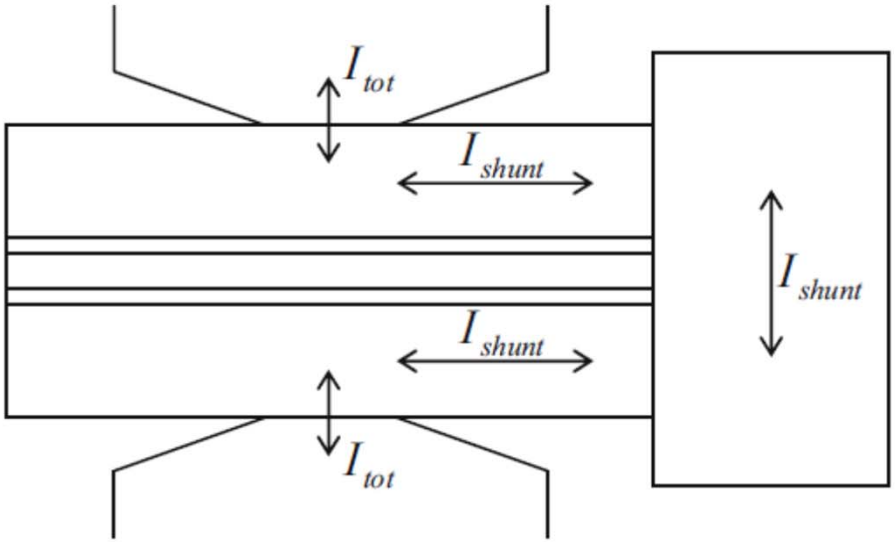


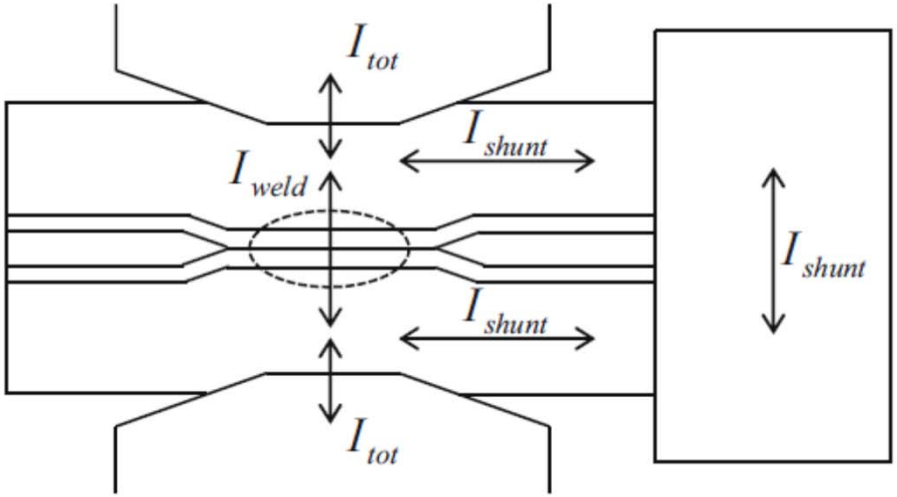
Saguës Tanco, J., Nielsen, C.V., Chergui, A., Zhang, W. and Bay, N. (2015): Weld nugget formation in resistance spot welding of new lightweight sandwich material. International Journal of Advanced Manufacturing Technology 80, 1137-1147.

Polymerer

Stål – Sandwich – Stål







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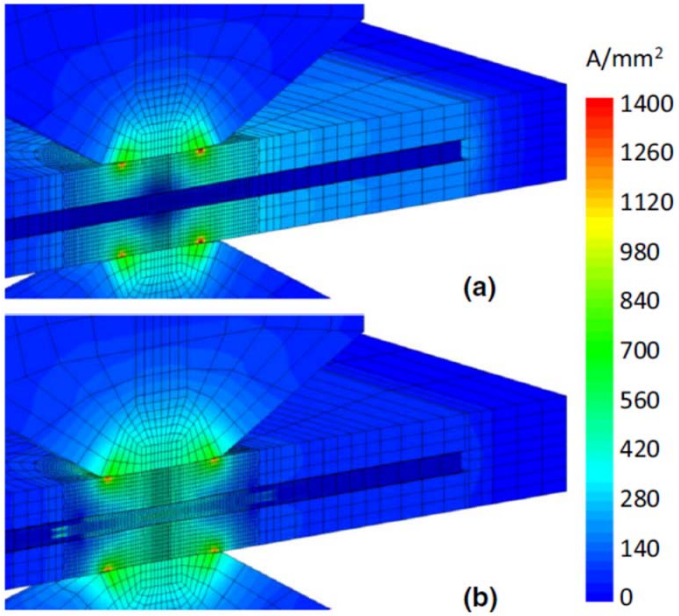
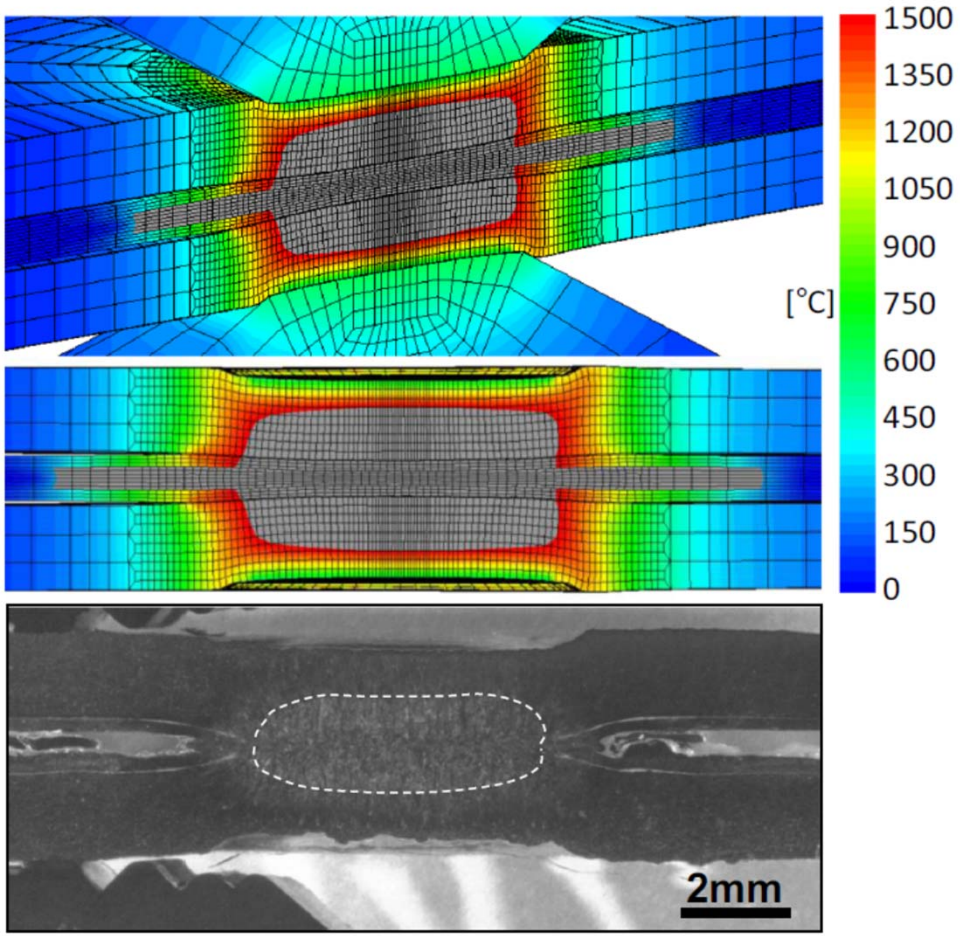
Polymerer

Stål – Sandwich – Stål





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Kontaktoplysninger

Lektor Chris Valentin Nielsen

cvni@mek.dtu.dk

DTU Danmarks Tekniske Universitet

Institut for Mekanisk Teknologi

2800 Kongens Lyngby